
INFLUENCE OF PLASTIC WASTE MORPHOLOGY ON THE COMPACTION PROPERTIES OF MARGINAL LATERITIC SOIL

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DOI: <https://doi.org/10.67203/sp.ICESID.2026>

ABSTRACT

The incorporation of plastic waste into lateritic soil provides an opportunity to reduce plastic pollution while modifying the compaction behaviour of earth materials used in road works. This study investigated the influence of the morphology and content of waste sachet-water plastic (SWPW) on the maximum dry density (MDD) and optimum moisture content (OMC) of a marginal lateritic soil. Used sachet-water bags collected in Kano State, Nigeria, were cleaned, air-dried and processed into fiber and powdered forms. The fiber pieces were approximately 5 mm wide and 25 mm long. Powdered SWPW was incorporated at 0-15% of dry soil mass at 2.5% intervals, while fiber SWPW was incorporated at 0-5% at 1% intervals. Compaction testing was carried out in accordance with BS 1377-4:1990. The untreated soil had an MDD of 1.94 g/cm³. With increasing powdered SWPW content, MDD decreased progressively to 1.33 g/cm³ at 15%, while OMC increased from 12.90% to 17.51%. Fiber SWPW similarly reduced MDD to 1.69 g/cm³ at 5% and increased OMC to 18.41%. The results demonstrate that SWPW morphology and dosage significantly influence the compaction response of lateritic soil, with the powdered form producing the larger reduction in dry density over the investigated range. The present study is limited to compaction characteristics; strength, durability and field-performance tests are required before structural suitability for pavement applications can be established.

Keywords: Plastic Waste; Fiber Content; Soil Stabilization; Geotechnical Properties

1. INTRODUCTION

According Plastic waste is a persistent environmental problem because of its high rate of generation and slow degradation. In Nigeria, single-use sachet-water packaging is widely used and discarded sachets frequently enter drains, waterways and open dumps. Reuse of this waste in geotechnical construction materials offers a potential route for diverting plastic from the environment while reducing demand for conventional materials. In soil engineering, waste plastics have been investigated as discrete fibres or inclusions, with reported effects on compaction and strength depending on plastic type, geometry, dosage and soil characteristics (Jalal & Hassan, 2021; Zukri et al., 2017; Munirwan & Jaya, 2019; Akinwumi et al., 2022).

Previous studies show that the response of soil to plastic inclusion is not governed by dosage alone. Jalal and Hassan (2021) reported that discrete plastic fibers altered the compaction characteristics of clayey soil and could also influence its mechanical behaviour. Zukri et al. (2017) investigated polyethylene and polypropylene in clay stabilization, while Munirwan and Jaya (2019) demonstrated that plastic waste content affects the geotechnical response of cement-stabilised soil intended for pavement layers. Akinwumi et al. (2022) similarly showed that recycled plastic inclusions can modify the engineering behaviour of soil. These studies establish the potential of plastic waste in geotechnical applications but also show that the form in which the plastic is introduced is important.

Most published studies have focused on plastic fibers, strips or shredded particles. Comparatively less attention has been given to the direct comparison of different morphologies prepared from the same waste stream, particularly waste sachet-water plastic incorporated into lateritic soils. Powdered plastic and elongated fibers differ markedly in particle geometry, surface area and interaction with the soil skeleton and may therefore produce different compaction responses. Understanding these differences is relevant when considering the reuse of sachet-water waste in earthworks and low-volume road construction.

This study therefore investigates the influence of two morphologies of waste sachet-water plastic - powdered SWPW (P-SWPW) and fiber SWPW (F-SWPW) - on the compaction characteristics of a marginal lateritic soil. The specific objective is to quantify the changes in maximum dry density (MDD) and optimum moisture content (OMC) with increasing plastic content and to compare the responses produced by the two morphologies. The study is intentionally limited to compaction behavior; strength and durability performance are outside the scope of the present investigation.

2. MATERIALS AND METHODS

2.1 Materials

Waste sachet-water plastic (SWPW) was collected from disposal locations in Kano State, Nigeria. The collected material was washed to remove adhering soil and other contaminants and then air-dried. Two morphologies were prepared from the same waste stream. For F-SWPW, the sachets were manually cut into fibres approximately 5 mm wide and 25 mm long. For P-SWPW, the cleaned and dried sachets were mechanically reduced to a powdered form before mixing with the soil. The plastic-specific density, tensile strength and detailed particle-size distribution of the powdered material were not experimentally determined in this study; this is recognised as a limitation and should be addressed in subsequent material-characterisation work

2.2 Methods

The natural lateritic soil was first characterised using index-property tests comprising particle-size distribution, Atterberg limits and specific gravity. Compaction tests were performed in accordance with BS 1377-4:1990 (U et al., 2022) using the light compaction procedure. The soil was compacted in a 1 L mould in three approximately equal layers using a 2.5 kg rammer falling through 300 mm, with 27 blows applied to each layer. For each mixture, the required quantity of SWPW was calculated as a percentage of the dry mass of soil and thoroughly dry-mixed with the soil to obtain a visually uniform distribution before water was added. P-SWPW contents of 0, 2.5, 5, 7.5, 10, 12.5 and 15% were investigated, while F-SWPW contents of 0, 1, 2, 3, 4 and 5% were investigated. For each plastic content, specimens were prepared over a range of moisture contents and the corresponding dry densities were determined. The moisture-density relationship was plotted and the MDD and OMC were obtained from the peak of the compaction curve. No curing period was adopted because the investigation concerned the immediate physical effect of SWPW on compaction rather than chemical stabilization. Strength and durability tests such as CBR and UCS were not included in the present experimental programme.

3. RESULTS

3.1 Material Basic Properties

With a plastic limit within the range of well-graded soil and a liquid limit just above the clayey soil zone, the soil sample exhibits strong structural qualities. In Nigeria, the soil may be used as a suitable fill for rural road bases without further processing or additions.

Table 1: Basic Geotechnical Properties of the soil

Parameter	Value
Liquid Limit	45%
Plastic Limit	30%
Plasticity Index	15%
Linear Shrinkage	8.0%
Specific Gravity	2.57
Max.Dry Density	1.94g/cm ³
Optimum Moisture	13.91%

3.2 Compaction Test Results

According to the findings of the compaction test, the moisture properties of soils improve as the P-SWPW concentration rises, suggesting that the addition of specific waste materials affects these properties (U et al., 2022). According to the research, finely processed SWPW is appropriate for rural roads in Nigeria's tropical environment because it enhances surface area and water retention capacity. However, when the P-SWPW concentration rises, MDD values fall, indicating possible changes in the soil. The results support the development of sustainable infrastructure and highlight the need of giving rural road building applications considerable thought. Compaction test findings for the fiber form of Sachet Water Plastic Waste (F-SWPW) demonstrate different patterns in soil compaction values as the amount of F-SWPW grows, as seen in figures 3 and 4. Perhaps because of its finer texture, the powdered form exhibits a greater decrease in OMC and an increase in MDD when compared to the fiber form. These findings are consistent with research on soils reinforced with fiber (Akinwumi et al., 2022). Nevertheless, the present results establish only the compaction response; the observed changes should not be interpreted as evidence of improved or reduced strength without CBR, UCS or other mechanical testing.

Table 2: Compaction characteristics of lateritic soil containing powdered and fibre SWPW

SWPW morphology	SWPW content (%)	MDD (g/cm ³)	OMC (%)
Powdered (P-SWPW)	0	1.94	12.90
Powdered (P-SWPW)	2.5	1.84	13.29
Powdered (P-SWPW)	5	1.75	14.00
Powdered (P-SWPW)	7.5	1.60	14.45
Powdered (P-SWPW)	10	1.50	15.50
Powdered (P-SWPW)	12.5	1.46	16.98
Powdered (P-SWPW)	15	1.33	17.51
Fibre (F-SWPW)	0	1.94	12.90
Fibre (F-SWPW)	1	1.84	13.29
Fibre (F-SWPW)	2	1.77	14.49
Fibre (F-SWPW)	3	1.73	14.87
Fibre (F-SWPW)	4	1.70	16.74
Fibre (F-SWPW)	5	1.69	18.41

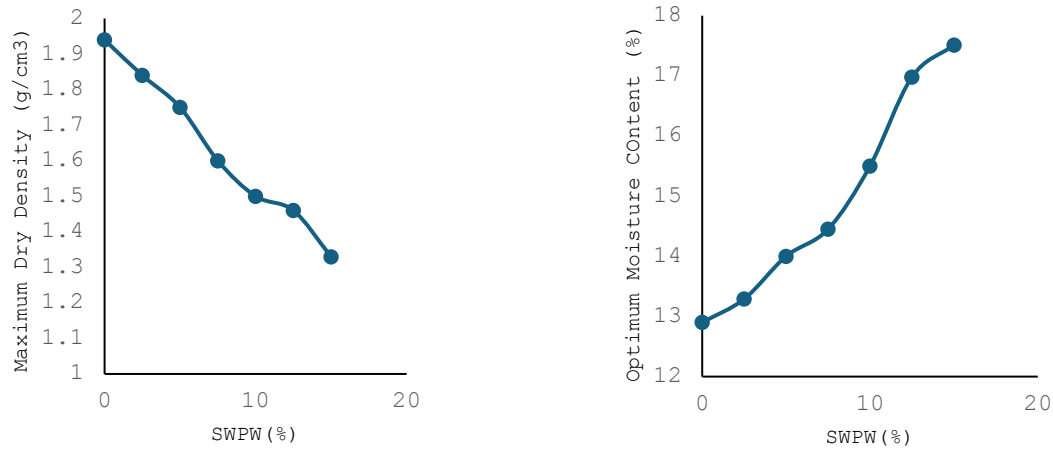


Figure 3: Variation of OMC and MDD with different % of sachet water powder

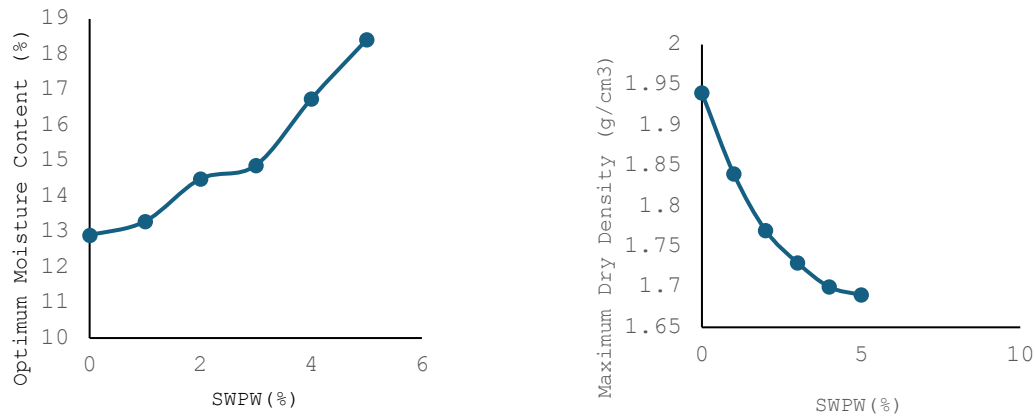


Figure 4: Variation of OMC and MDD with different % of sachet water fiber

4. CONCLUSION

This study demonstrates that the morphology and dosage of waste sachet-water plastic significantly influence the compaction characteristics of the investigated marginal lateritic soil. For P-SWPW, increasing the plastic content from 0 to 15% reduced MDD from 1.94 to 1.33 g/cm³, while OMC increased from 12.90 to 17.51%. For F-SWPW, increasing the fibre content from 0 to 5% reduced MDD from 1.94 to 1.69 g/cm³ and increased OMC to 18.41%. Thus, both morphologies produced lower dry densities and higher optimum moisture requirements, although the magnitude of the response differed with morphology and dosage. The powdered form produced the greater overall reduction in MDD, whereas the fibre form produced the highest measured OMC at 5%. These findings are useful for understanding the compaction behavior of lateritic soil containing recycled sachet-water plastic; however, they are not sufficient to establish structural suitability for road-base or subbase applications. The principal limitation of the present study is the absence of strength and durability testing and detailed physical characterization of the plastic additive. Future work should therefore include CBR, UCS or shear-strength tests, soaked/durability assessment, microstructural evaluation and field compaction trials to identify technically acceptable and environmentally sustainable SWPW contents for road earthworks.

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